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# CONTROL OF BOTRYTIS ROT OF PEARS WITH CHEMICALLY TREATED WRAPPERS[1]

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## CHARACTERISTICS OF THE DISEASE

Botrytis rot[2] is a serious storage disease of both pears and apples, often ranking second only to blue-mold rot, and for the pears of the Pacific Northwest often taking first place among all storage diseases. Many thousands of dollars are known to have been lost in the late shipments of pears of the 1929 crop on account of this disease.[3]

Botrytis rot is usually known on the market as gray-mold rot, the name being descriptive of the gray mycelium that appears on the fruit or on the wrapper in the late stages of decay. (Fig. 1.) It is also known as cluster rot, a particularly appropriate name, since several to a dozen or more affected fruits are frequently found at one location in the package. The fungus mycelium grows from one fruit to another in such a way that the rotting fruits are held together and it is often possible by careful examination to trace the development of large clusters to a single initial rotten fruit. Figure 2 shows a cluster of rots taken from a commercial package on the New York market by Henry Hartman, of the Oregon Agricultural Experiment Station, in which he traced the rot in 39 pears to a single initial rot. Botrytis rot is darker brown in color than blue-mold rot and the affected tissue is relatively much firmer. In the advanced stages of the disease the affected fruit may be flecked with black sclerotial bodies.

Botrytis is a low-temperature fungus,[4] being able to continue its growth and produce decay at the usual storage temperature of 32° F.

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[1] Acknowledgement is made to Charles Brooks, principal pathologist, Bureau of Plant Industry, for assisting in the preparation of the manuscript and for taking the records on the lot of fruit shipped to Washington, D. C.

[2] Caused by *Botrytis* sp., apparently *B. cinerea*.

[3] Henry Hartman, of the Oregon Agricultural Experiment Station, estimated that for the 1929 crop the loss on the last 25 cars of pears sold in New York City averaged $1 a box.

[4] BROOKS, C., and COOLEY, J. S. TEMPERATURE RELATIONS OF APPLE-ROT FUNGI. Jour. Agr. Research 8: 139–164, illus. 1917.

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The ordinary apple wrapper does not prevent the spread of Botrytis rot in the package; in fact, it has sometimes seemed to favor its spread. In the spring of 1928 the writer's attention was called to the numerous brown spots on some Anjou pears that were being repacked on account of Botrytis rot. A careful study of the pack revealed the fact that these brown spots or incipient rots resulted from the spread of the fungus from initial clusters of rotting fruit. The larger rots were near the initial rotten fruit and the smaller ones more distant. The distribution of the rotten pears in the box, as well as their size and location, indicated that the fungus must be advancing through the paper and attacking fruits as far as two or three layers away from the initial rotten fruit. A microscopic examination of the wrappers from fruit in the first stages of rot showed that the mycelium of a fungus was present in the paper. This indicated that, if the fruit were wrapped in a paper impregnated with a salt toxic to the fungus, the spread of the rot in the package might be greatly reduced.

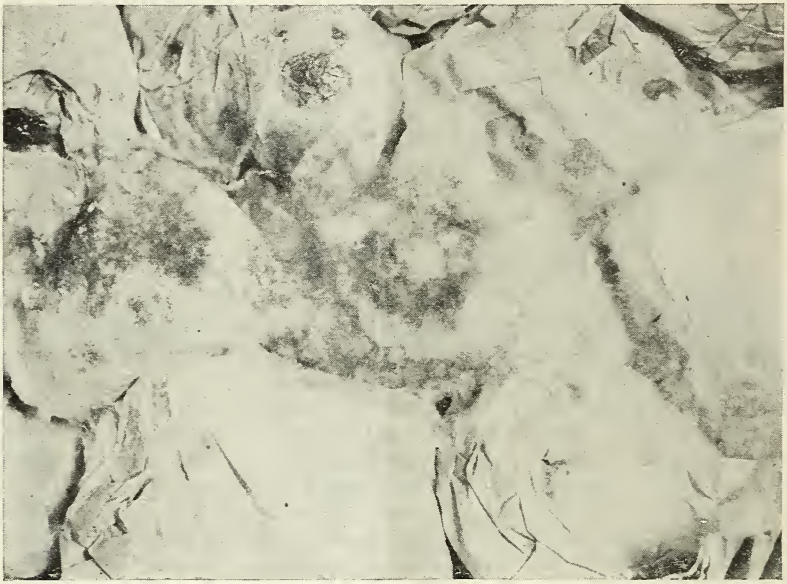

FIGURE 1.—A nest of rotting pears showing the weft of *Botrytis mycelium* over the outside of the wrappers

## CHEMICALLY TREATED WRAPPERS

The special wrappers used in these experiments were prepared by saturating ordinary wrappers with known chemical solutions and hanging them singly to dry. In preparing the wrappers by this method the percentage of the toxic salt in the dry wrapper was higher than that in the solution. The wrappers saturated with a solution containing 2.5 per cent copper sulphate ($CuSO_4.5H_2O$) were found on a dry-weight basis to carry about 3.5 per cent of their weight in copper sulphate, or 1.4 per cent of their weight in metallic copper. In the experiments that follow, these wrappers are described according to the percentage of the salt in the solution with which they were saturated.

A part of the experiments in 1930 were made with commercially treated wrappers. The paper was prepared by one of the mills in the Northwest at practically the same cost as oiled paper. It had a slightly bluish tint, but this was not found objectionable. The first runs of the paper were found to be much more brittle than the untreated paper, but in a later run this difficulty was largely overcome.

## STORAGE EXPERIMENTS

### METHODS

To test the efficacy of the chemically treated wrappers in preventing the spread of the disease, pears sufficient to make one complete layer in a box were inoculated with Botrytis, wrapped in the treated papers, and packed in a box with sound fruit similarly wrapped. Sound and inoculated pears were similarly packed in untreated wrappers.

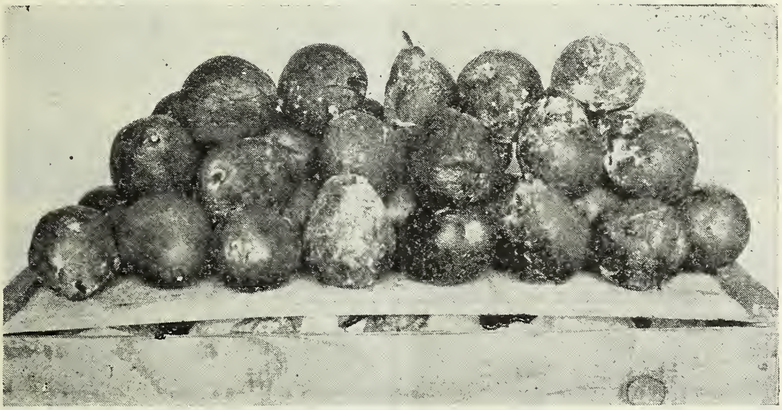

FIGURE 2.—A cluster of 39 rotten pears apparently infected from a single rotten fruit; a commercial pack on the New York market, April, 1929. (Photographed by Henry Hartman)

The fruit was prepared for inoculation by immersing it for about five minutes in 50 per cent alcohol and rinsing in sterile water.

Inoculation was accomplished by forcing spores or spores and mycelium into the fruit, using cultures of Botrytis that had been obtained from rotting pears. By exercising extreme care to prevent outside infection, the inoculated fruit remained remarkably free from blue mold or other contaminations. In estimating the percentage of rot the inoculated fruit was not counted.

With the exception of the preliminary experiments in the spring of 1929, the fruit was taken directly from a mechanical washer, wrapped as specified, stored immediately at 31° F., and held for the usual storage period for the variety.

## RESULTS

In a preliminary storage experiment started March 9 and continued until May 9, 1929, very satisfactory control of Botrytis rot was secured with wrappers saturated with a 10 per cent solution of copper sulphate.

In a second experiment started April 18 and continued until June 19, 1929, wrappers were impregnated with 2 per cent and also with 10 per cent solutions of copper sulphate, nickel sulphate, ferrous sulphate, sodium chromate, and sodium carbonate,[5] respectively. The results of the experiment indicated that all of these salts had value in the control of Botrytis, but that copper sulphate was most effective and, all things considered, best suited for the purpose. The

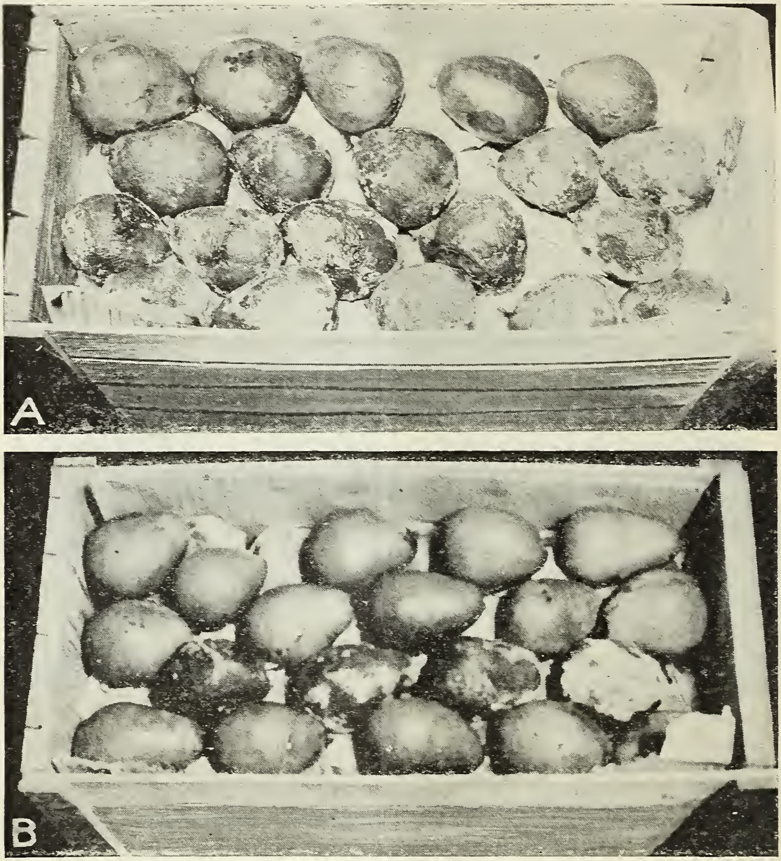

FIGURE 3.—Anjou pears after four months' storage, showing spread of Botrytis rot from inoculated layer (second layer from bottom; boxes opened from side): A, Pears in untreated wrappers; B, in wrappers treated with 2.5 per cent solution of copper sulphate

wrappers treated with the 2 per cent solution of copper sulphate gave poorer control than those treated with the 10 per cent solution.

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[5] BATEMAN, E., and BAECHLER, R. THEORY OF THE MECHANISM OF PROTECTION OF WOOD BY PRESERVATIVES. PART VII. SOME EXPERIMENTS ON THE TOXICITY OF INORGANIC SALTS. Amer. Wood Preservers Assoc. Proc. 23: 41–48. 1927.

In the fall of 1929 and also in 1930 further tests were made as to the most desirable chemical treatment for the paper. The results are shown in Tables 1 and 2 and in Figures 3 and 4.

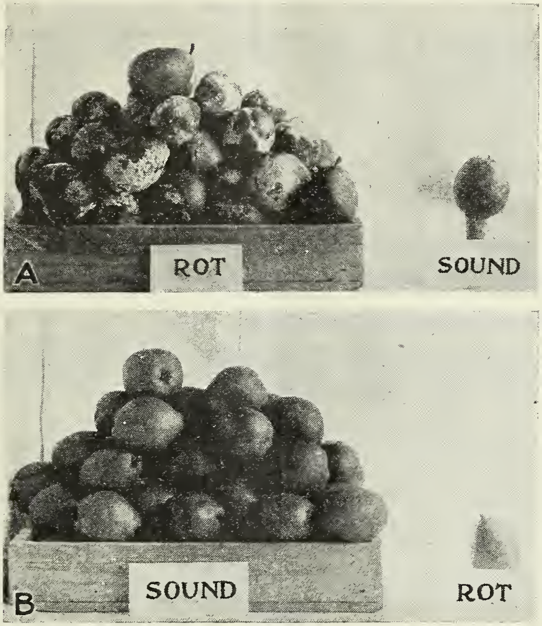

FIGURE 4.—Boxes of Easter pears as they appeared after four months' storage. In each box the pears in the second layer from the bottom were inoculated with Botrytis: A, Pears in untreated wrappers; all but one rotten. B, Pears in wrappers treated with 2.5 per cent solution of copper sulphate; rot spread to only one uninoculated fruit

TABLE 1.—*Anjou pears stored in paper wrappers untreated and treated with zinc sulphate and iron sulphate*[1]

| Treatment of wrapper | Fruit affected with Botrytis rot |
|---|---|
| | *Per cent* |
| Untreated | 86 |
| Impregnated with 1 per cent zinc sulphate | 6 |
| Impregnated with 2.5 per cent zinc sulphate | 3 |
| Impregnated with 5 per cent zinc sulphate | 0 |
| Impregnated with 10 per cent zinc sulphate | 3 |
| Impregnated with 10 per cent iron sulphate | 15 |

[1] The fruit was harvested Oct. 5, 1929, wrapped and stored Nov. 23, 1929, and removed from storage Apr. 15, 1930. Two layers of sound fruit were placed above and one below the inoculated fruit.

TABLE 2.—*Winter Nelis, Easter, and Anjou pears in paper wrappers, untreated and treated with copper sulphate*[1]

| Treatment of wrapper | Winter Nelis, 1929 | | Easter Beurre, 1929 | | Anjou, 1929 | | Anjou, 1930 | |
|---|---|---|---|---|---|---|---|---|
| | Pears | Rot | Pears | Rot | Pears | Rot | Pears | Rot |
| | *Number* | *Per cent* | *Number* | *Per cent* | *Number* | *Per cent* | *Number* | *Per cent* |
| Untreated | 60 | 78.3 | 64 | 98.4 | 150 | 98 | 105 | 80.1 |
| Impregnated with copper sulphate: | | | | | | | | |
| 1.0 per cent | 90 | 10 | 64 | 29.7 | 66 | 38 | -------- | -------- |
| 1.5 per cent | -------- | -------- | -------- | -------- | -------- | -------- | 225 | 4.2 |
| 2.0 per cent | -------- | -------- | -------- | -------- | -------- | -------- | 226 | 1.9 |
| 2.5 per cent | 74 | 0 | 64 | 1.6 | 61 | 1 | 304 | 1.7 |
| 5.0 per cent | 92 | 0 | 63 | 0 | 63 | 0 | 231 | 1.4 |
| 7.5 per cent | 74 | 0 | 54 | 0 | 69 | 2 | -------- | -------- |
| 10.0 per cent | 68 | 0 | 68 | 1.6 | 75 | 1.5 | -------- | -------- |

[1] The Winter Nelis pears were wrapped and stored Oct. 8, 1929, and were removed from storage Apr. 15, 1930; the Easter pears, wrapped and stored Oct. 17, 1929, were removed from storage Apr. 14, 1930; the first lot of Anjou pears, wrapped and stored Sept. 4, 1929, was removed from storage Feb. 25, 1930; and the second lot, wrapped and stored Sept. 15, 1930, was removed from storage Feb. 18, 1931. In the 1929 experiments about 28 inoculated pears were placed in each box, making one complete layer; in the 1930 experiment 6 inoculated pears were included in each box.

It will be seen from the results that the zinc salt was slightly less effective than the copper, and the iron salt decidedly less effective.

It will be noted that wrappers soaked in a 1 per cent copper-sulphate solution did not appreciably control the spread of the rot, while those treated with a 1½ per cent solution were fairly effective and those treated with solutions containing 2 per cent or more of the salt gave almost complete control.

In the fall of 1930 the Apple Growers' Association of Hood River, Oreg., succeeded in obtaining sufficient commercially treated wrappers for 30,000 boxes of pears. This paper contained at least 1.4 per cent of copper or the equivalent of impregnation in a 2½ per cent solution of copper sulphate. An experimental lot of fruit was packed by a professional packer in the regular commercial way with no unusual care to prevent the breaking of the wrapper. Part of this fruit was placed in cold storage at Hood River and part of it was shipped to Washington, D. C., under refrigeration, and placed in cold storage immediately upon arrival. The results of the experiment are shown in Table 3. With the pears stored at Hood River, the few rots that were evidently initial infections and not due to the spread of the fungus from other pears were not counted in the percentage of rot.

The results show that the wrappers commercially treated with copper sulphate gave a very high degree of rot control. In most instances where a spread of rot occurred with the treated wrappers it could be traced to breaks in the paper.

TABLE 3.—*Spread of Botrytis rot in Anjou pears packed in wrappers commercially treated with copper sulphate*

[The fruit was picked and packed September 15, 1930]

| Treatment | Stored at Hood River, Oreg. | | Stored at Washington, D. C. | |
|---|---|---|---|---|
| | Pears | Affected by spread of Botrytis rot | Pears | Affected by spread of Botrytis rot |
| | *Number* | *Per cent* | *Number* | *Per cent* |
| No inoculations: | | | | |
| Untreated wrappers | 308 | 10. 6 | 110 | 10. 0 |
| Treated wrappers | ---------- | ---------- | 110 | 0 |
| Six inoculated pears in each box: | | | | |
| Untreated wrappers | 99 | 80. 1 | 110 | 92. 3 |
| Treated wrappers | 286 | 1. 7 | 110 | 12. 5 |

## OIL AND COPPER SULPHATE TREATED WRAPPERS

In attempting to overcome the brittleness of the wrapping paper treated with a water solution of copper sulphate, the manufacturers introduced the copper salt into the paper in combination with oil. On November 6, 1930, an experiment was started with this paper using cold-storage fruit and methods similar to those recorded above. From 30 to 60 pears were used in each lot, five of which were inoculated with Botrytis and placed in the next to the bottom layer in the box. They were stored November 6, and the record of rots was taken May 26, 1931. The results are shown in Table 4.

TABLE 4.—*Percentage of Anjou and Winter Nelis pears affected by Botrytis rot when stored in paper wrappers untreated and commercially treated with oil and with oil plus copper sulphate*

| Treatment of wrappers | Anjou | Winter Nelis |
|---|---|---|
| | *Per cent* | *Per cent* |
| About 18 per cent oil | 79. 3 | ---------- |
| Check (untreated) | 78. 8 | 48. 0 |
| 10 per cent oil plus 3 per cent copper | 1. 7 | 0 |
| 20 per cent oil plus 1.4 per cent copper | 9. 4 | 4. 5 |

Although this is a preliminary experiment it indicates that the use of paper wrappers treated with oil and copper sulphate is effective in controlling the spread of Botrytis rot of pears. From a comparison of the results given in Tables 2 and 4 it seems probable that somewhat more copper sulphate may be required in the oiled than in the unoiled wrappers.

## SOME PRACTICAL EXPERIMENTS

The outstanding success of the chemically treated paper wrappers in preventing the spread of Botrytis rot raises several practical questions. Is there any danger of injuring the fruit? Does an objectionable amount of copper sulphate adhere to the fruit?

In anticipation of the first question, additional lots of Anjou pears were packed in the 10 per cent and also in the 2 per cent copper-sulphate treated wrappers in connection with the experiments reported in Table 1, and stored as usual till February 25. From February 25 to March 22 the boxes of pears were brought to the laboratory four times at intervals of several days and held at room temperature for eight hours and then returned to cold storage. After this alternate warming and cooling the fruit was left in the laboratory four days to give ample opportunity for any injury to become evident. The harsh treatment resulted in some browning of the skin in all lots, but it was as prevalent on the fruit in the untreated wrappers as on that in the treated wrappers.

Data obtained on the 1930 crop, however, indicate that copper injury may sometimes occur. (Fig. 5.) In order to obtain further information regarding the possibility of copper injury under extreme conditions, two boxes of fruit having one-half the fruit in each box wrapped in untreated paper and one-half wrapped in commercially treated paper were removed from cold storage three times at intervals of three weeks or more and allowed to remain in a warm moist atmosphere for a day or more and then returned. The fruit in one box showed no copper injury, while in another box 11 per cent of the fruit in the treated paper showed traces of copper injury. There was not enough injury in any case, however, to affect the grade.

In 1930 much of the fruit that was packed in treated wrappers was washed and had a thin film of moisture over the surface when wrapped, but it soon became dry in the handling operations and no harm resulted. In the case of one small lot of fruit that was cooled in storage and then packed in a warm atmosphere, sufficient moisture condensed on some of the pears to form droplets over the surface. After wrapping in paper treated with copper sulphate, and storing, most of this fruit was found to be free from copper injury, but there were occasional pears in two of the boxes that showed enough black spotting from copper injury to be discriminated against in the market. The injury ranged from very slight to sufficiently black spots to affect as much as 3 per cent of the surface of the fruit.

Regarding his observations on the New York market in the winter of 1930–31, Henry Hartman, of the Oregon Agricultural Experiment Station, reports that slight injury was observed on a few lots packed in treated wrappers, but not enough to affect the grade in any case.

It is evident that care must be exercised in packing wet fruit in copper-sulphate treated wrappers, and also that some injury may result from excessive sweating. However, the fruit in about 30,000 boxes of the 1930 crop of pears was wrapped in such chemically treated wrappers and went through the regular market channels with no complaint from the consignees in regard to copper injury.

In order to ascertain whether enough copper sulphate is left on the fruit to be objectionable from the food standpoint, analyses[6] were made of pears that had been packed in wrappers treated with 10 per cent copper sulphate and held four months in cold storage. The results showed only a trace of copper on the fruit, it being less than 0.0005 grain to the pound, which is far below the tolerance limit.

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[6] The copper analyses for the fruit and also those previously reported for the wrappers were made by the junior writer.

## SUMMARY

*Botrytis* sp. (apparently *B. cinerea*) is the cause of a serious storage rot of apples and pears that spreads to sound fruits in contact with decaying ones.

It has been found that it may spread through the fruit wrappers to fruits that are not adjacent, as well as to those that are.

The spread of Botrytis rot has been controlled on pears by the use of wrappers impregnated with 2.5 per cent solution of copper sulphate, the dry wrapper carrying about 1.4 per cent of its dry weight in metallic copper in the form of copper sulphate.

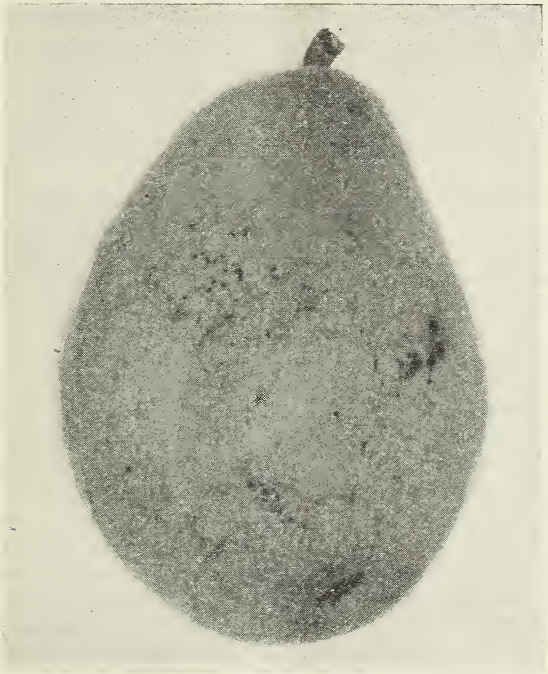

FIGURE 5.—Copper injury on Anjou pear packed wet in a copper-sulphate treated wrapper

Preliminary experiments also indicate that the spread of Botrytis rot may be effectively controlled by the use of oiled paper wrappers impregnated with copper sulphate.

Experimental evidence has been obtained that injury may result from packing wet pears in chemically-treated wrappers, but the fruit in about 30,000 boxes of the 1930 crop of Anjou pears was packed in commercially treated paper with no report of significant injury.

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